Supplemental Draft CALSIM II Documentation

Prepared by Daniel B. Steiner

April 24, 2006

The attached draft documents were prepared subsequent to the documentation titled "Draft CALSIM II San Joaquin River Model", U.S. Bureau of Reclamation, April 2005. The supplemental documents represent documentation of additional CALSIM II development efforts during 2005. These efforts are incorporated into the CALSIM II model presented at the April 24, 2006 SWRCB workshop concerning modifications of CALSIM II and application of the model on the San Joaquin River.

<u>Documents</u>

1. **Technical Memorandum – Completion of Task 1.6 for USJRBSI, November 9, 2005**
2. **Enhancements to CALSIM II-Lander Avenue to Gravelly Ford, September 2005**
3. **Water Quality Assumption for the San Joaquin River at Lander Avenue (Node 611), October 2005**
4. **San Joaquin Hydrology Extension, June 2005**

T E C H N I C A L   M E M O R A N D U M

MWH

Subject:	Completion of Task 1.6 for USJRBSI	**Date:**	November 9, 2005
Prepared by:	Anna Fock	**File Number:**	
Reviewed by:	Yung-Hsin Sun		

BACKGROUND AND PURPOSE

MWH is currently preparing the Feasibility Report and Environmental Impact Study/Report for the Upper San Joaquin River Basin Storage Investigation (USJRBSI), which was authorized under Public Law 108-7 in fiscal year 2003. The purpose of Task 1.6 of USJRBSI is to enhance hydrology and water quality assumption for the San Joaquin River upstream of Lander Avenue in CALSIM, and thus improve CALSIM analytical functions for the San Joaquin River between Friant Dam and Maze Avenue.

AREAS REQUIRED IMPROVEMENTS

In the last phase of CALSIM development for the San Joaquin River, the following conditions were identified as limitations on CALSIM application in USJRBSI alternative evaluation for river restoration and water quality improvement:

1. One accretion and one depletion arc were used to represent water gains and losses along the San Joaquin River upstream of the confluence of Merced River (Newman). Such coarse spatial resolution has limited representation from downstream of Friant Dam to Newman. These two arcs should be disaggregated to a degree adequate to simulate existing operations and to estimate water quality through flow balance.
2. Water quality calculation began at the San Joaquin River at Lander Avenue in electrical conductivity (EC). EC for this upstream boundary was calculated from an EC-flow regression equation developed from historical observations. For USJRBSI alternative evaluation, releases will be made from Friant Dam to reach Mendota Pool for river restoration and water quality improvement. Under this boundary condition, any change in the source of water supply for Mendota Pool cannot be reflected because Lander Avenue is downstream of Mendota Pool. As hydrologic components upstream of Lander Avenue would be disaggregated, EC values that reflect the source quality could be assigned for water quality calculation. The EC calculation could then

be moved further upstream to enhance the water quality representation of the San Joaquin River below Friant Dam.

3. Refuge return operations around Mendota Pool were not represented at the same level of details as refuge operations along the Grasslands Bypass. For refuge return operations along the Grasslands Bypass, modifications in annual return amount, monthly return schedule, and EC values were made in the previous development for Water Quality Module. These adjustments were based on WETMANSIM developed for the draft Exchange Contractors' Environmental Impact Statement/Report to simulate refuge returns of post-2000 firm Level 2 refuge operations. As water quality calculation would be moved further upstream, similar modifications should be made on refuge returns to Mendota Pool. Routing of this refuge water in CALSIM should be verified and modified if necessary.

Improvements for Item 1 belongs to hydrology enhancements, while the remaining to water quality.

HYDROLOGY / WATER QUALITY ENHANCEMENTS

Under Task 1.6, CALSIM enhancements for the above areas were in two major categories hydrology and water quality. Hydrology enhancements focused on increasing spatial resolution of the San Joaquin River upstream of Lander Avenue through schematic modifications and accretion/depletion disaggregation. The new CALSIM schematic is shown in **Figure 1** and detailed descriptions of hydrology enhancements were shown in **Attachment A**. Water quality enhancements focused on modifying water quality inputs and calculation as followed:

1. Removed EC-flow boundary condition at Lander Avenue (Node 614). Performed EC calculation at nodes 605, 595, 587, 589, 607, 608, 609, 610, 611, and 614 through salt balance.
   [Files modified: vernalis_wqmin_Disag.wresl, vernalis_wqpulse_Disag.wresl, WQ_Bound_Disag.wresl]

2. Updated water quality of Delta-Mendota Canal (DMC) inflows into the Mendota Pool, C708 and C607BVAMP, with numbers developed by Dan Steiner in August 2005 (Steiner's August analysis, **Table 1**). These numbers are average monthly EC values varied with Sacramento Valley wetness conditions (Sacramento Valley hydrologic classification) in CVP contract year. [File modified: EC_Table_MPool.table]

3. R607West is an aggregate of return sub-arcs from refuge (R607i from Mendota Water Management Authority, Mendota WMA) and agriculture (the remaining sub-arcs) after applying DMC water. EC values for agricultural returns in R607West are equal to Stenier's August analysis plus 500 μS/cm. The 500 μS/cm is an assumption to represent increase salt load caused by applying DMC waters for irrigation. This number is equal to the difference between long-term average monthly of Steiner's August analysis (533 μS/cm) and EC_SWR619 (996 μS/cm) from water year 1922 through 2003. EC_SWR619 was the SJRIO year-type monthly EC assumption for surface returns to Orestimba Creek. Its monthly values were originated from SJRIO

assumptions. Returns incurred at Orestimba Creek are mainly from CVP contractors using DMC water for irrigation. Water quality assumptions for R607i are explained below. [File modified: wq_defs_Disag.wresl]

4. Although R607i is shown in schematic, it is not simulated in CALSIM. R607i was created to represent Mendota WMA refuge returns into the Mendota Pool. Both refuge returns R607i and R614L (Grassland Water District) are originated from diversions from Mendota Pool (D607C) and have similar operations. D607C annual contract amount is 94.4 thousand acre-feet (TAF), with 27 TAF to Mendota WMA and the remaining to Grasslands Water District. R607i is assumed to have the same monthly return schedule, annual return-delivery ratio (which is 0.61), and water quality as R614L. These assumptions were from WETMANSIM (**Table 2**). [Files modified: WestSideReturns.wresl, WSReturnC1.wresl, WSReturnC2.wresl, WSReturnC3.wresl, and WSReturnC5.wresl]

5. Assigned EC values to flows into the above nodes with 100 μS/cm for every month every year, except of C708 and R607West. The EC value of 100 μS/cm was based on Steiner's August analysis. Detailed explanation is documented in **Attachment B**, Water Quality Assumption for the San Joaquin River at Lander Avenue (Node 611). Water quality assumptions for C708 and R607West were explained above. [Files modified: wq_defs_Disag.wresl and EC_US_Lander.table]

6. In the previous phase of Water Quality Module development, salts from tile drains and groundwater base flows were embedded into the salt closure terms. In the current development, they were then separated from the closure terms and added to nodes 630 and 636 as Salt630 and Salt636. [Files modified: vernalis_wqmin_Disag.wresl, vernalis_wqpulse_Disag.wresl, WQ_Bound_Disag.wresl, and Accretion_def.wresl]

7. Recalibrated salt closure terms AbvNwmnResLoad (for nodes 614 and 620) and BtwMazeNwmnResLoad (for nodes 630 and 636) to accommodate the above changes in water quality assumptions and to best fit with EC targets at Newman and Maze

Table 1. Average Monthly Year-Type Water Quality for Delta-Mendota Canal Inflows into the Mendota Pool

Sacramento Valley Water Year Type	CALSIM Sacramento CVP Index	Average Monthly EC Values (μS/cm)											
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Wet	1	550	460	470	407	334	364	391	398	500	532	540	550
Above Normal	2	542	463	471	450	355	373	391	491	552	623	550	550
Below Normal	3	544	469	468	438	365	379	475	537	540	630	556	551
Dry	4	620	553	480	440	349	485	610	599	572	630	678	615
Critical	5	814	889	882	766	785	693	699	690	742	924	732	760

Data Source:

Table 2. Average Monthly Return Schedule and EC Values Monthly for R607I

Month	Return Distribution	EC Values (μS/cm)
Oct	5.8%	1,006
Nov	15.3%	1,121
Dec	12.4%	1,058
Jan	7.9%	1,120
Feb	13.9%	1,430
Mar	9.4%	2,570
Apr	2.3%	2,245
May	5.0%	1,000
Jun	4.5%	1,000
Jul	2.7%	1,200
Aug	1.9%	1,325
Sep	18.9%	1,051

Source:
2004 WETMANSIM

Figure 1. New CALSIM Schematic for the San Joaquin River

Place holder

Attachment A. Hydrology Enhancements to CALSIM II San Joaquin River Basin – Lander Avenue to Gravelly Ford, September 2005

Attachment B. Water Quality Assumption for the San Joaquin River at Lander Avenue (Node 611), October 2005

Enhancements to CalSim II
San Joaquin River Basin - Lander Avenue to Gravelly Ford
September 2005

Introduction and Background

The San Joaquin River Basin is represented in CalSim II as described in documentation provided to support version SJR_2001X10A_PRELIM_040105. Since that effort, additional model development efforts[1] have extended the San Joaquin River hydrology of CalSim II through the year 2003, revised several model parameters, and implemented minor logic modifications. This technical document describes changes to CalSim II that have subsequently been implemented to better depict the hydrology and operations of the San Joaquin River upstream of the confluence with the Merced River, specifically the net accretions/depletions upstream of the Merced River and the operations of the San Joaquin River between Friant Dam and "Lander Avenue".

Up to this point in time, the model generally depicted the San Joaquin River upstream of the location geographically near Lander Avenue as a large single area for the purpose of establishing a hydrologic balance for flows reaching this point. Several known inflows to the area were debited by several other known or estimated diversions and losses, and compared to the estimated flow of the San Joaquin River upstream of the Merced River. Essentially a net accretion/depletion was calculated to represent the amount of water flowing in the San Joaquin River that could not be explained by explicitly known or assumed water diversions, seepage and inflows. This net accretion/depletion was also influenced by the occurrence of gage error or reporting error, if any, in any of the mass balance components. The methodology of the approach was considered appropriate for the initial phase of CalSim II development; however, it was anticipated that studies specifically concerning different water management strategies and facilities upstream of the Merced River confluence would require a refinement to the current CalSim II model protocols.

The objective of this subsequent effort was to enhance the analytical functions embedded in CalSim II for depicting accretions (rainfall runoff) and depletions (seepage) for the affected area (Friant Dam to Lander Avenue). The mass-balance approach previously used for estimating net accretion/depletion (a CalSim II input value that was determined at "Newman" and applied at Lander Avenue) is now replaced with a calculation of rainfall runoff for the area and functions for explicit stream reach losses. Also enhanced was the depiction of the water quality of the San Joaquin River at Lander Avenue. Previously the water quality at this location was determined as a function of flow based on historical records. Water quality at this location is now determined by a mass balance of inflows and their associated water quality (see MWH documentation).

The hydrologic and water quality refinements developed by this refinement provide a more explicit depiction of San Joaquin River's flow and water quality processes along the San Joaquin River between Friant Dam and Vernalis, add additional hydrologic resolution between Friant Dam and the confluence with Merced River, and allow greater flexibility in the investigation of alternative operations and facilities upstream of the Merced River.

[1] SAN JOAQUIN HYDROLOGY EXTENSION – Documented in memorandum file name SAN JOAQUIN HYDROLOGY EXTENSION_revised.doc, June 30, 2005.

Revised Representation

The CalSim II depiction of the San Joaquin River Basin upstream of Lander Avenue has been refined to better represent physical paths of flow and hydrologic processes. Figure 1 provides a geographical orientation for the refined CalSim II nodes between Friant Dam (Node 18) and Lander Avenue (Node 611). A revised schematic for the affected area is illustrated in Figure 2 and a CalSim II schematic for the entire San Joaquin River area is included in Figure 7. A schematic map of structures, flood routing, and reach hydraulic capacities of the San Joaquin River Flood Control Project[2] is included in figure 8 to provide additional background for the geographical area.

Definition of River Reaches

The San Joaquin River and Eastside Bypass upstream from the confluence of the San Joaquin and Merced Rivers are disaggregated into reaches defined by the following upstream and downstream nodes:

San Joaquin River Path

- Friant Dam (Node 18) to Gravelly Ford (Node 603), not modified
- Gravelly Ford (Node 603) to Bifurcation (Node 605), not modified
- Bifurcation (Node 605) to Mendota Pool (Node 607), not modified
- Mendota Pool (Node 607) to Sack Dam (Node 608), added
- Sack Dam (Node 608) to the Sand Slough Control Structure (Node 609), added
- Sand Slough Control Structure (Node 609) to Mariposa Bypass Return (Node 610), added
- Mariposa Bypass Return (Node 610) to Lander Avenue (Node 611), added
- Lander Avenue (Node 611) to Mud/Salt Slough (Node 614), not modified

Eastside Bypass Path

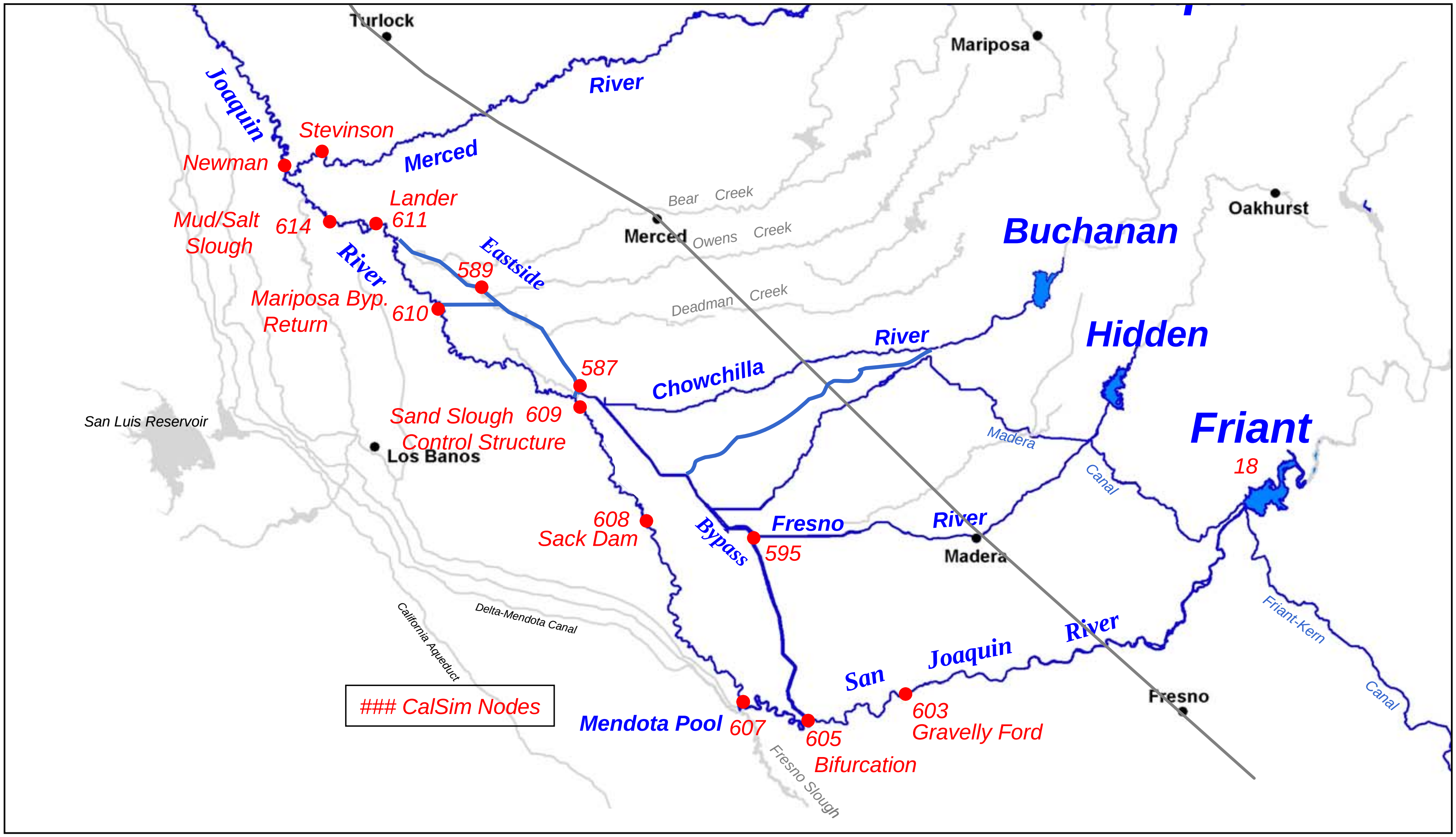
- Bifurcation (Node 605) to Fresno River (Node 595), not modified
- Fresno River (Node 595) to Chowchilla River (Node 587), not modified
- Chowchilla River (Node 587) to Eastside Bypass (Node 589), added
- Chowchilla River (Node 587) to SJR Mariposa Bypass Return (Node 610), added
- Mariposa Bypass (Node 589) to Lander Avenue (Node 611), added

The additional stream reaches and disaggregation of stream reaches allows a more refined routing of flood control and other San Joaquin River releases. The modifications also facilitate better functionality within the model to estimate reach water quality, accretions and depletions. Node 608 (Sack Dam) was added for water quality and flood control functionality. Node 609 (Sand Slough Control Structure), Node 610 (Mariposa Bypass Return) and Node 589 (Mariposa Bypass) were added for routing functionality.

Node 605 (San Joaquin River Bifurcation Structure) continues to provide functionality for dividing San Joaquin River flow between the Eastside Bypass and San Joaquin River. Node 595 (Eastside Bypass at Fresno River) will depict the confluence of the bypass flows and flows from the Fresno River. Node 587 (Eastside Bypass at Chowchilla River) will depict the confluence of bypass flows and flows from the Chowchilla River complex of streams including Berenda and Ash sloughs. Node 587, Node 589 and Node 610 will depict the bifurcation of flows to the Eastside Bypass and the Mariposa Bypass. Node 589 also provides a point where regional rainfall runoff is introduced to the stream.

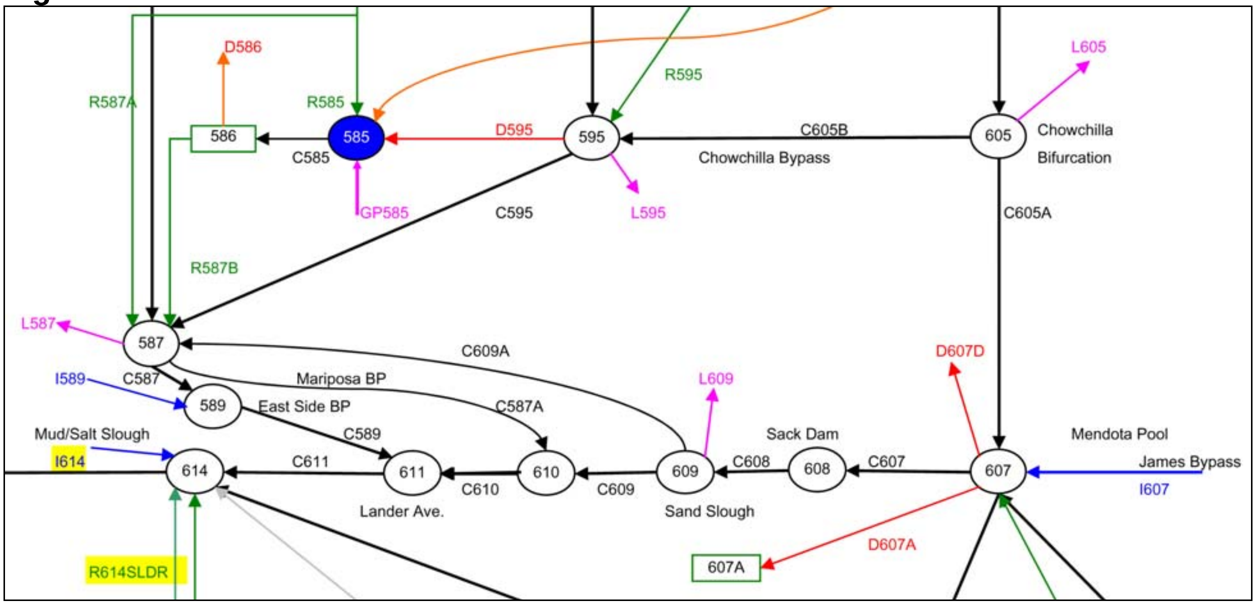
[2] Draft Restoration Strategies for the San Joaquin River, Stillwater Sciences, February 2003.

Figure 1



Turlock
Mariposa
Joaquin
River
Stevinson
Newman
Merced
Lander
611
Mud/Salt
Slough
614
Bear Creek
Merced
Owens Creek
Buchanan
Oakhurst
Eastside
River
589
Mariposa Byp.
Return
610
Deadman Creek
Hidden
River
587
Chowchilla
Sand Slough 609
Control Structure
San Luis Reservoir
Los Banos
Madera
Canal
Friant
18
608
Sack Dam
Bypass
Fresno
595
River
Madera
Delta-Mendota Canal
California Aqueduct
Friant-Kern
Canal
San
Joaquin
River
CalSim Nodes
Mendota Pool
607
605
Bifurcation
603
Gravelly Ford
Fresno
Fresno Slough

Figure 2 - Revised CalSim II Schematic in Affected Area



River Accretions and Depletions

Up to this time, the primary CalSim II method of estimating accretions/depletions (unexplained flow) for major river reaches of the San Joaquin River and its tributaries, including the large area above Lander Avenue involved the performance of a mass-balance using gage records between upstream and downstream flow points and accounting for known and assumed inflows and diversions between those points. This methodology accounted for water entering and leaving river reaches using the following formula:

Accretion / Depletion (unexplained flow) =

+	Downstream River gage
-	Upstream River gage
+	Diversions
-	Return flow

Generically, for the CalSim II hydrologic input for the San Joaquin River Basin, the calculation determines a net accretion/depletion (unexplained flow) value that represents precipitation runoff, historical stream-groundwater interaction, and gage and estimation errors. When applied to the other components of flow that arrive at a node due to explicit CalSim II stream operations such as reservoir releases, diversions and return flows, this net accretion/depletion term provides a "true-up" for the flow at that location that is due to the processes that are not explicitly modeled by CalSim II. This generic approach was initially applied to the large area above Lander Avenue (actually it was applied to entire area above the confluence of the Merced River) and the results are a part of version SJR_2001X10A_PRELIM_040105.

Due mainly to the lack of long-term stream flow records at key locations, use of a mass-balance approach to estimate net accretions/depletion for the San Joaquin River Basin upstream from the Merced River confluence was identified to be in need of refinement or replacement. The generic methodology was found to be problematic for this area when attempting to estimate potential stream losses during parts of the year when there is little or no historical flow information to rely upon. Also, during rainfall periods, the lack of stream flow records and the use of the streams by districts for conveyance of their diversions make the estimation of runoff from the rain-fed streams throughout this region unreliable. Because the mass-balance approach yielded unreliable results, an alternative method was applied to estimate accretions and depletions for this region. The revised methodology employs two facets of hydrology to depict the non-operated components of stream flow: 1) river reach losses, explicitly depicting seepage losses (depletions) for selected stream reaches, and 2) rainfall runoff, explicitly depicting surface water accretions. These two components of stream flow replace the net “unexplained flow” value previously applied within CalSim II at Lander Avenue (I611), and are described as follows.

River Reach Losses: CalSim II now explicitly depicts the depletion of flow from each stream reach in the area due to seepage. The revised or added river reach loss protocols are described below by river reach. The specific values included in the protocols (e.g., the loss parameters) are currently based on estimates developed from review of limited historical records and engineering judgment. These values can be modified in the future as additional information is developed. Several river reaches in the affected area were not modified. These reaches include: San Joaquin River from Friant Dam to Gravelly Ford, Fresno River, Chowchilla River, and Mendota Pool. The losses associated with these reaches are described in the existing CalSim II documentation, and can be modified in quantity if appropriate.

For the San Joaquin River reach between Gravelly Ford (Node 603), and upstream of where water would join the backwater of Mendota Pool (Node 607) the protocol assumes the loss of the first 100 cfs flowing past Gravelly Ford, and then an additional 5 percent of the flow greater than 100 cfs past Gravelly Ford. The calculated loss is reported as L605.

For San Joaquin River water that reaches the Mendota Pool, and for water reaching the Mendota Pool from Fresno Slough, CalSim II currently assigns losses at Mendota Pool through the south of Delta delivery logic. These values are assumed to include losses for the reach of the San Joaquin River below Mendota Dam to Sack Dam.

The San Joaquin River below Sack Dam (Node 608) to the Sand Slough Control Structure (Node 609) is essentially a dry streambed except during flood releases. When wetted, this reach could have some channel loss due to seepage. The loss protocol assigns a constant channel loss of 13 cfs for this 13 mile stretch of river. If flow occurs past Sack Dam, this channel loss assumption will slightly reduce the flow past Sack Dam by approximately 1,000 acre-feet per month. The calculated loss is reported as L609.

At the Sand Slough Control Structure (Node 609) water currently is routed to the Eastside Bypass although it is possible to route flow to the San Joaquin River. The loss protocol currently assigns no seepage loss to flows below the control structure to either flow path (to Node 610 and downstream, or to Node 587 and downstream).

San Joaquin River water that does not flow downstream to the San Joaquin River at the bifurcation structure is diverted to the Chowchilla Bypass. Flows in the Chowchilla Bypass are assumed to be subject to seepage losses. The protocol assigns a constant loss to flow in the bypass based on the length of travel that the flow incurs before combining with other flows (if any) in the bypass. The current protocol assumes a distance-conveyed loss value similar to losses assumed for the reach below Gravelly Ford. To estimate losses in the Chowchilla Bypass, the length of channel from the Bifurcation to the confluence with the Fresno River system is considered. The length of the Chowchilla Bypass from the Bifurcation structure to the Fresno River is about 15 miles, and losses are assumed to be 7cfs/mile, therefore losses in this reach of the Chowchilla Bypass are 105 cfs. The portion of the bypass below the Fresno River to the confluence with the routing of flow from the Sand Slough Control Structure (approximately at the confluence of the Chowchilla River) is about 16 miles with a comparable loss of 112 cfs assumed for this reach. During drier conditions, flows from the Fresno and Chowchilla systems do not reach the Chowchilla Bypass (due to their localized stream losses) and San Joaquin River flow routed to the Chowchilla Bypass will be subject to losses for the entire reach (approximately 31 miles). The calculated losses along the Eastside Bypass are reported as L595 and L587.

Rainfall Runoff: Streams in the area upstream of Lander Avenue will at times have a flow component derived from the runoff of precipitation from adjoining and tributary lands. This runoff is not associated with the controlled releases from reservoirs or the return flows associated with irrigation operations. This component of flow is defined as rainfall runoff, an accretion to stream flow.

The San Joaquin River Basin upstream from Lander Avenue and downstream from Friant Dam has little or no snowmelt runoff. Also, in general, groundwater is in an over draft condition in this region and is essentially disconnected from the surface water system; therefore, there is little or no groundwater contribution to stream flow. Return flows from the area are also considered to be minimal. Rainfall runoff is the primary contributor to accretions and thus this effort focused on estimating rainfall runoff.

Use of precipitation data as the parameter to establish runoff accretions proved to result in large inaccuracies. This parameter appears to be problematic due to an inability to simplistically describe the storage response of the soils in the region, e.g., it is difficult to capture the function of filling and draining soils after precipitation. The approach that resulted in the most representative and responsive accretion estimate proved to be one that relies on long-term flow records of rain-fed streams in the area. This approach eliminated the need to develop rainfall-runoff coefficients and the need to consider additional algorithms that recognized soil storage effects on rainfall runoff.

There are several rain-fed streams in this region that contribute to San Joaquin River flow above the confluence of the Merced River. The objective was to create an estimate of runoff entering the San Joaquin River from these streams based on known long-term stream flows at upstream unimpaired locations. The Fresno and Chowchilla Rivers are two rain-fed rivers with long-term records[3], and were used as the basis for developing the accretions. To best relate the flow characteristics of these two rivers to the runoff characteristics of the smaller streams within this basin, correlations between these two rivers and smaller rivers were developed.

Four small creeks referred to as the Merced Streams Group capture rainfall in the northern most portion of this region. Burns, Bear, Owens, and Mariposa creeks make up the Merced Streams group. Monthly flow from these individual creeks were compared to flow in the Chowchilla River upstream from Eastman Lake to determine if they have similar runoff characteristics. Figure 3 contains a time-series plot of these creeks compared to Chowchilla River flow and Figure 4 contains a plot of the total Merced Stream Group and the Chowchilla River. Based on these plots and a correlation it is assumed that the Merced Streams Group has similar characteristics as the Chowchilla River, and that the flow in the Chowchilla River flow could be used as the basis to determine runoff from this area. A comparison of Chowchilla River flow to Fresno River flow shows that these two basins behave in a similar manner, refer to Figure 5. Thus, because of the similar behavior of rain-fed streams in this region an average Fresno and Chowchilla River flow are used as the basis for accretions for the entire region.

[3] Fresno and Chowchilla river hydrology is described in CALSIM II documentation for version SJR_2001X10A_PRELIM_040105

The average of the Fresno and Chowchilla river flow provides an indication of the temporal occurrence and relative magnitude of runoff in this region, but must be factored to represent runoff for the entire region. The factor is determined by iteratively adjusting a multiplier times the average of the flow for the Fresno and Chowchilla rivers and adding this flow (I589) into CalSim II at Node 589. The multiplier is adjusted until the resulting San Joaquin River flow at Newman compares well with the historical flow at Newman. The accretion (I589) for the region was determined to be best represented by 250% of the average of the Fresno and Chowchilla river flow. Figure 6A and 6B present the results of the historical and simulated San Joaquin River flow at Newman after the rainfall runoff has been added to the other components of flow developed by the CalSim II operation.

Other Operational Parameters

The operational protocols for the San Joaquin River were also modified during this refinement. These refinements were implemented to better represent the current operations of the San Joaquin River between Friant Dam and Lander Avenue.

The flow routing at the Bifurcation (Node 605) was modified to limit San Joaquin River routing (C605A) to a maximum of 1,300 cfs which is a generalized assumption (non-damaging flow) based on recent experience. The remainder of San Joaquin River flow at Node 605 will be routed to the Chowchilla Bypass (C605B). C605A is additionally constrained to not contribute to flows below Sack Dam (C608) in excess of 4,500 cfs (an assumed maximum flood control capacity). At times, C605A could be reduced to zero if inflow from Fresno Slough (I607) equals or exceeds Mendota Pool demands and losses, and 4,500 cfs below Sack Dam. At times, the flow below Sack Dam may exceed 4,500 cfs due to inflow from Fresno Slough.

The currently implemented routing of flow at Sand Slough Control Structure diverts the entire flow at Node 609 to the Eastside Bypass. Subsequently, the flow occurring in the bypass below the Chowchilla River (Node 587) is routed back to the San Joaquin River through the Mariposa Bypass (C587A) up to the first 8,500 cfs, with the remainder of any flow routed down the lower end of the bypass to Node 589. All flows combine at Lander Avenue (Node 611).

Figure 3

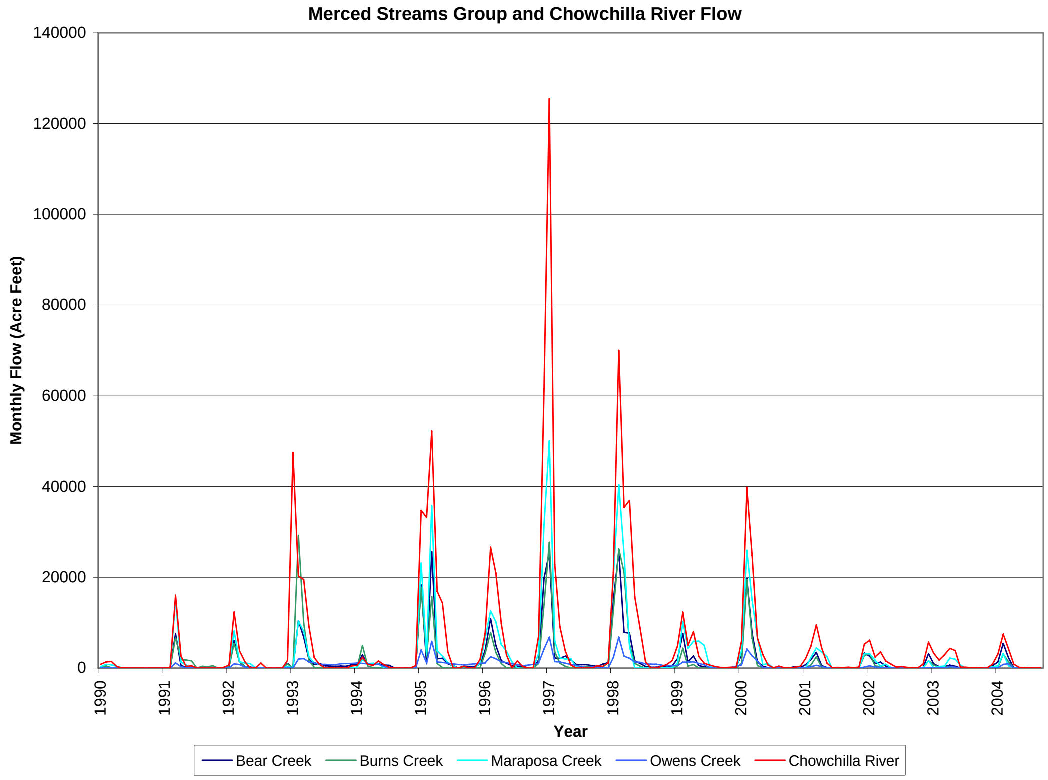


Figure 4

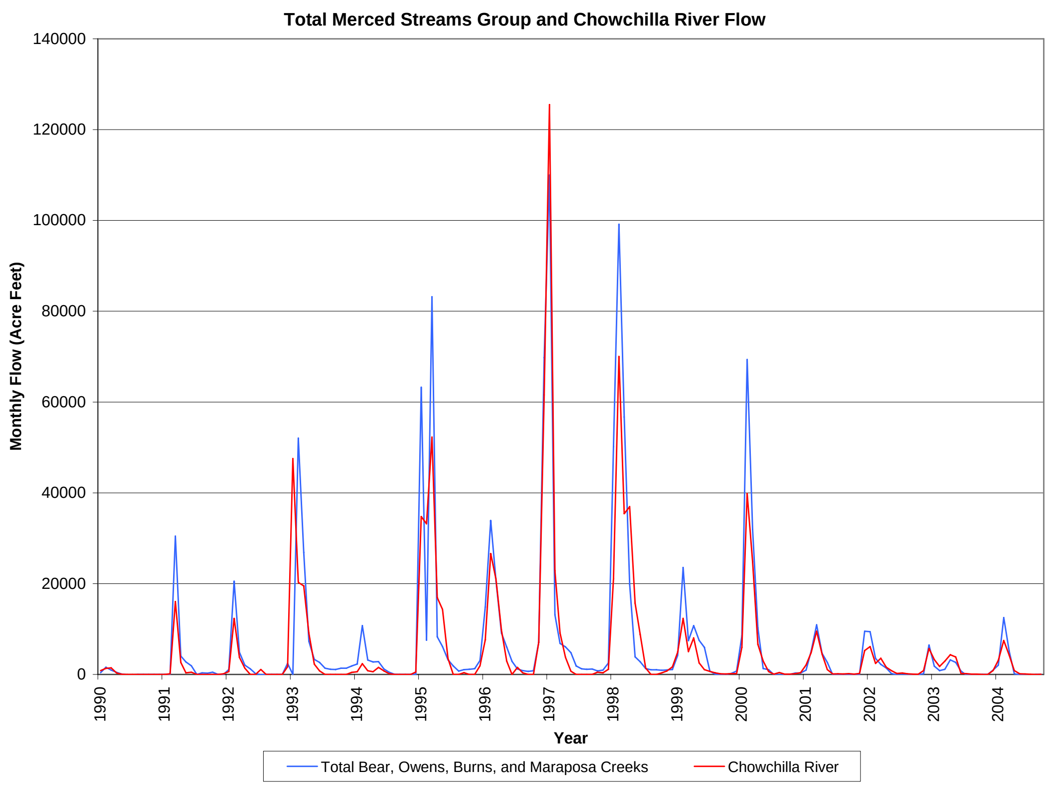
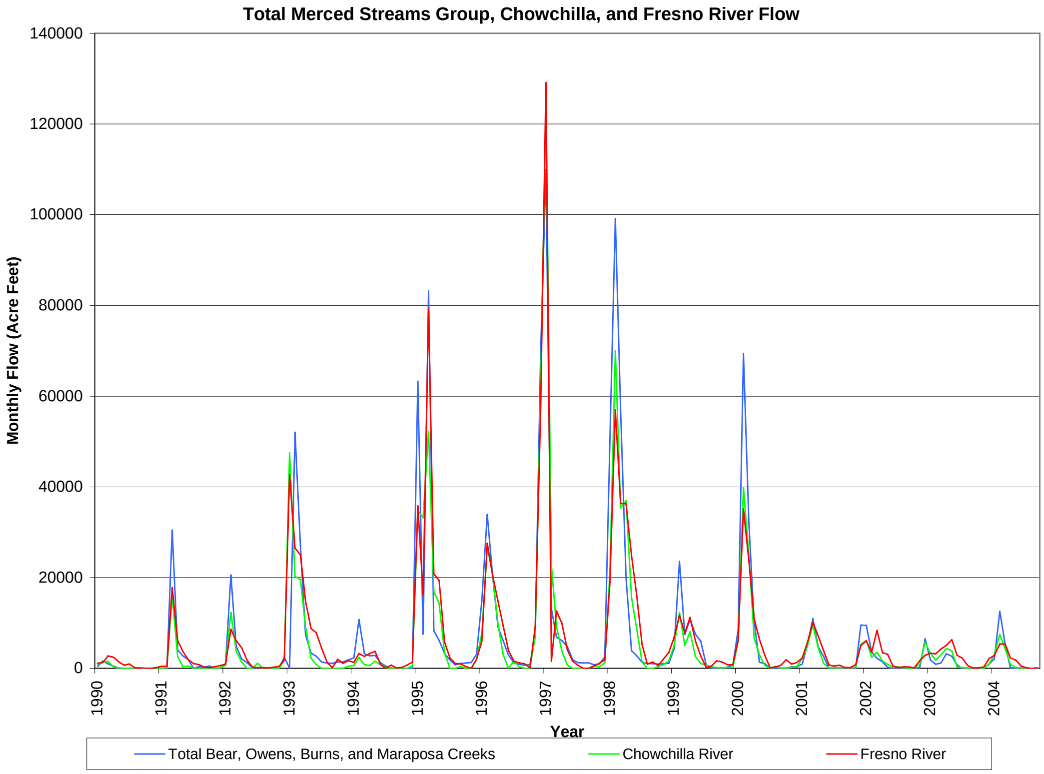


Figure 5



Total Merced Streams Group, Chowchilla, and Fresno River Flow
Monthly Flow (Acre Feet)
140000
120000
100000
80000
60000
40000
20000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
Total Bear, Owens, Burns, and Maraposa Creeks
Chowchilla River
Fresno River

Figure 6A - San Joaquin River flow at Newman

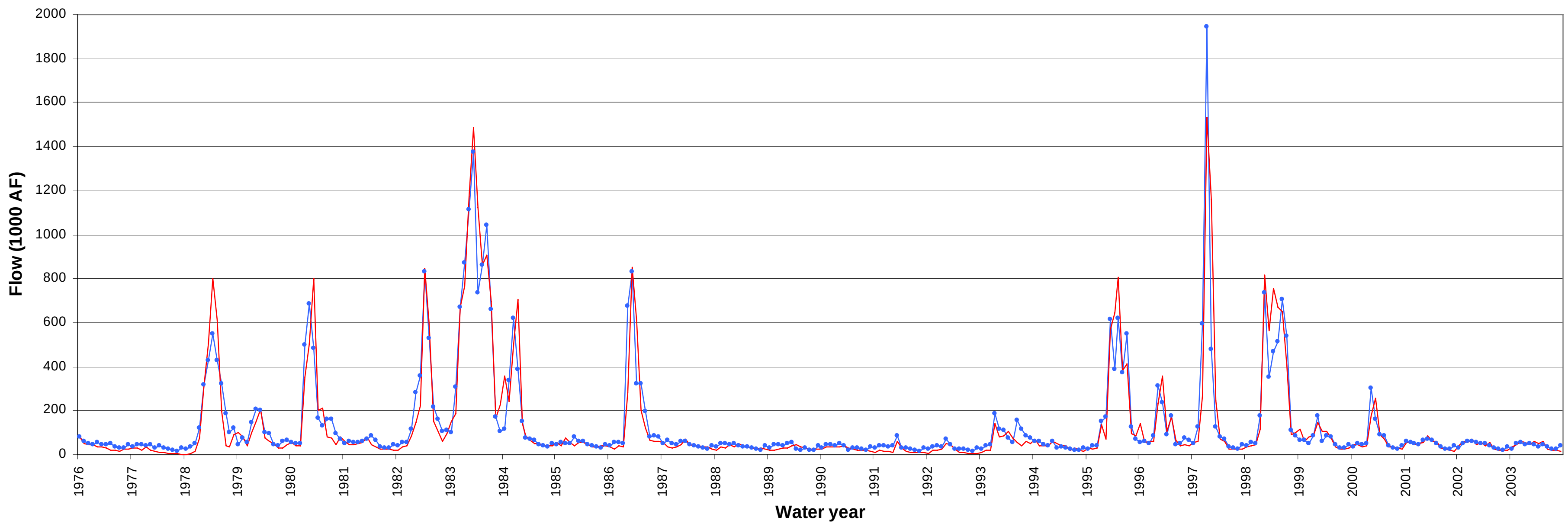


Figure 6B - Newman flow with Y axis scale set to for lower flows

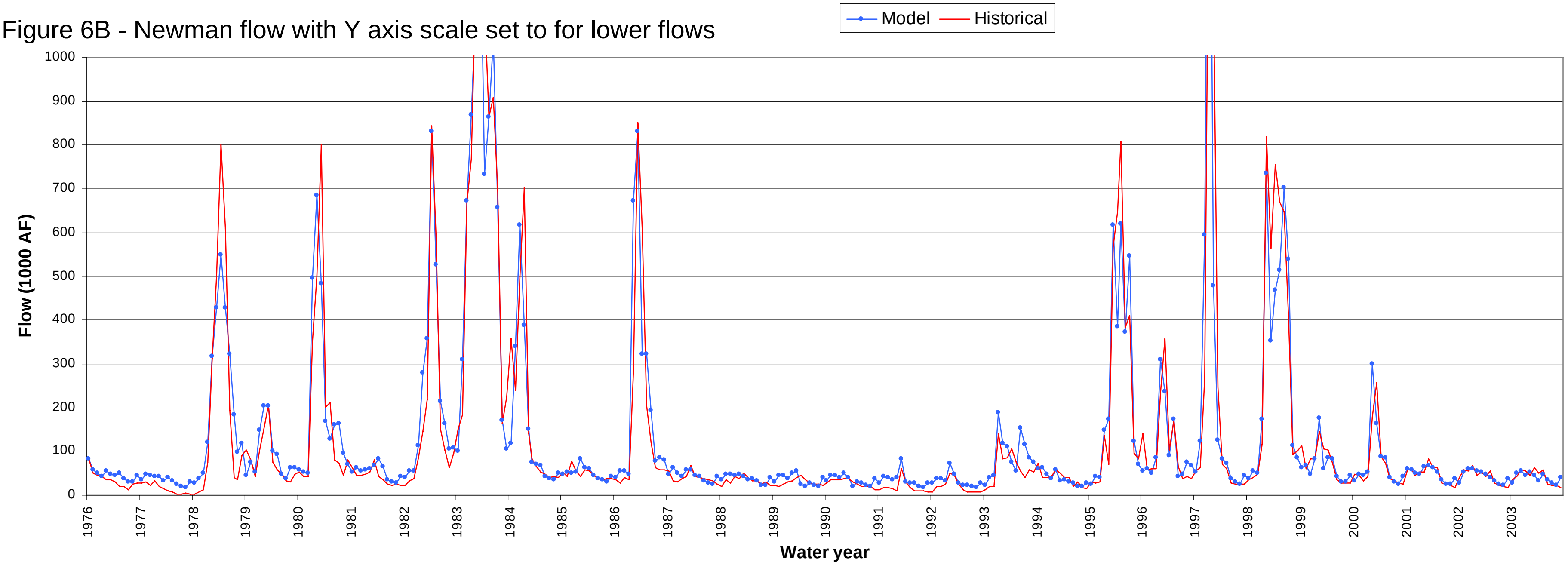


Table 1 San Joaquin River Accretion Upstream from Newman (I589)

water year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	tota
									1000 Acre Feet				
1922	0	1	28	23	94	65	43	32	10	4	1	0	301
1923	1	5	39	40	27	19	57	27	14	6	1	1	237
1924	1	1	3	3	5	9	8	3	0	0	0	0	33
1925	0	3	3	3	40	19	33	19	11	1	0	0	132
1926	1	1	3	3	17	10	40	12	3	0	0	0	90
1927	0	18	13	10	79	34	45	19	11	3	1	0	233
1928	2	14	10	15	21	39	29	10	3	0	0	0	143
1929	0	2	3	3	7	11	11	11	5	1	0	0	54
1930	0	0	0	8	11	19	8	6	3	0	0	0	55
1931	0	1	1	3	3	2	2	2	1	0	0	0	15
1932	0	0	48	34	112	27	24	24	14	4	0	0	287
1933	0	0	2	8	8	16	14	12	10	1	0	0	71
1934	0	0	3	5	13	9	6	2	1	0	0	0	39
1935	0	3	6	45	26	44	81	35	19	5	1	0	265
1936	1	2	2	11	142	38	45	27	14	3	1	0	286
1937	1	2	6	11	145	81	48	35	18	5	1	1	354
1938	1	2	25	30	162	286	74	47	29	14	4	2	676
1939	4	5	6	7	15	23	22	11	4	1	0	1	99
1940	3	2	2	72	71	56	37	23	8	2	0	0	276
1941	1	2	36	38	108	93	73	36	24	9	3	2	425
1942	1	2	36	38	42	45	40	29	16	7	1	0	257
1943	1	6	7	49	36	104	37	21	8	2	1	0	272
1944	1	1	2	5	24	34	16	14	7	1	0	0	105
1945	0	10	6	6	81	75	36	19	12	3	0	0	248
1946	1	3	22	10	8	22	24	15	6	1	0	0	112
1947	1	8	14	6	11	10	8	5	2	0	0	0	65
1948	0	1	1	1	2	10	34	14	8	2	0	0	73
1949	0	0	1	2	6	30	11	13	6	1	0	0	70
1950	0	1	1	10	26	9	15	10	4	1	0	0	77
1951	0	51	65	36	28	26	15	13	4	1	0	0	239
1952	0	2	25	91	33	122	54	24	13	7	1	1	373
1953	1	2	13	30	9	11	12	11	8	2	0	0	99
1954	0	1	2	7	13	25	18	13	5	1	0	0	85
1955	0	1	4	12	7	9	10	15	5	1	0	0	64
1956	0	1	174	104	43	21	22	24	8	2	0	0	399
1957	1	1	2	3	8	15	10	18	7	1	0	0	66
1958	0	1	4	9	39	103	163	25	12	6	2	1	365
1959	1	1	2	5	21	10	7	5	1	0	0	0	53
1960	0	1	1	3	16	10	10	8	2	0	0	0	51
1961	0	2	3	3	4	5	4	3	1	0	0	0	25
1962	0	0	2	3	114	45	16	11	8	2	0	0	201
1963	1	1	1	16	45	22	56	28	11	4	1	0	186
1964	1	9	5	7	6	9	11	9	4	1	0	0	62
1965	0	7	51	70	20	20	63	18	10	3	1	1	264
1966	1	15	17	19	16	12	10	8	2	1	0	0	101
1967	0	2	43	28	24	59	171	60	23	9	2	1	422
1968	1	2	4	5	11	11	8	6	2	0	0	0	50
1969	0	2	11	178	192	120	76	30	17	8	2	1	637
1970	3	3	6	50	18	47	13	10	6	1	0	0	157
1971	0	3	18	16	9	12	10	11	7	1	0	0	87
1972	0	2	8	5	9	7	7	5	2	0	0	0	45
1973	0	2	4	22	93	81	36	18	7	1	0	0	264
1974	1	4	13	34	12	51	58	16	6	1	0	0	196
1975	0	2	4	6	42	59	44	26	12	3	0	0	198
1976	1	2	3	2	6	8	5	3	1	1	0	0	32
1977	0	1	1	2	1	1	1	1	1	0	0	0	9
1978	0	0	9	72	128	123	113	42	13	4	1	1	506
1979	0	3	3	35	52	70	31	16	6	2	0	0	218
1980	1	2	3	64	84	80	30	18	9	3	0	0	294
1981	0	1	3	11	8	17	11	4	1	1	0	0	57
1982	1	4	7	66	65	108	148	25	10	5	2	2	443
1983	4	29	83	126	173	267	91	58	17	7	3	2	860
1984	2	24	68	28	25	22	13	6	3	1	1	0	193
1985	1	5	5	5	12	18	12	4	2	0	0	0	64
1986	1	3	7	8	171	112	26	13	5	1	0	0	347
1987	1	1	2	3	8	13	4	2	2	1	0	0	37
1988	0	1	2	5	3	5	6	2	1	0	0	0	25
1989	0	0	2	2	4	14	5	2	1	0	0	0	30
1990	0	1	1	3	3	5	3	2	1	1	0	0	20
1991	0	0	0	1	1	42	11	5	3	1	1	0	65
1992	0	0	1	2	26	12	7	2	0	2	0	0	52
1993	0	0	4	113	59	56	30	14	11	5	2	0	294
1994	2	1	3	2	7	4	5	7	2	0	1	0	34
1995	0	1	2	88	62	164	47	42	12	3	1	2	424
1996	0	0	5	17	68	52	31	15	5	4	2	1	200
1997	0	20	148	318	31	27	17	6	2	1	0	0	570
1998	1	2	4	50	159	90	92	51	31	8	1	2	491
1999	1	4	6	15	30	16	24	11	5	1	1	2	116
2000	2	1	1	15	94	61	22	12	4	0	1	1	214
2001	2	1	2	6	13	25	14	6	1	1	1	0	72
2002	0	1	13	15	8	15	6	5	1	1	1	0	66
2003	0	3	11	8	6	9	12	13	4	3	1	0	70
Average	1	4	15	29	42	44	32	16	7	2	1	0	193
Max	4	51	174	318	192	286	171	60	31	14	4	2	860
Min	0	0	0	1	1	1	1	1	0	0	0	0	9

Figure 7 - CalSim Schematic of San Joaquin River Basin

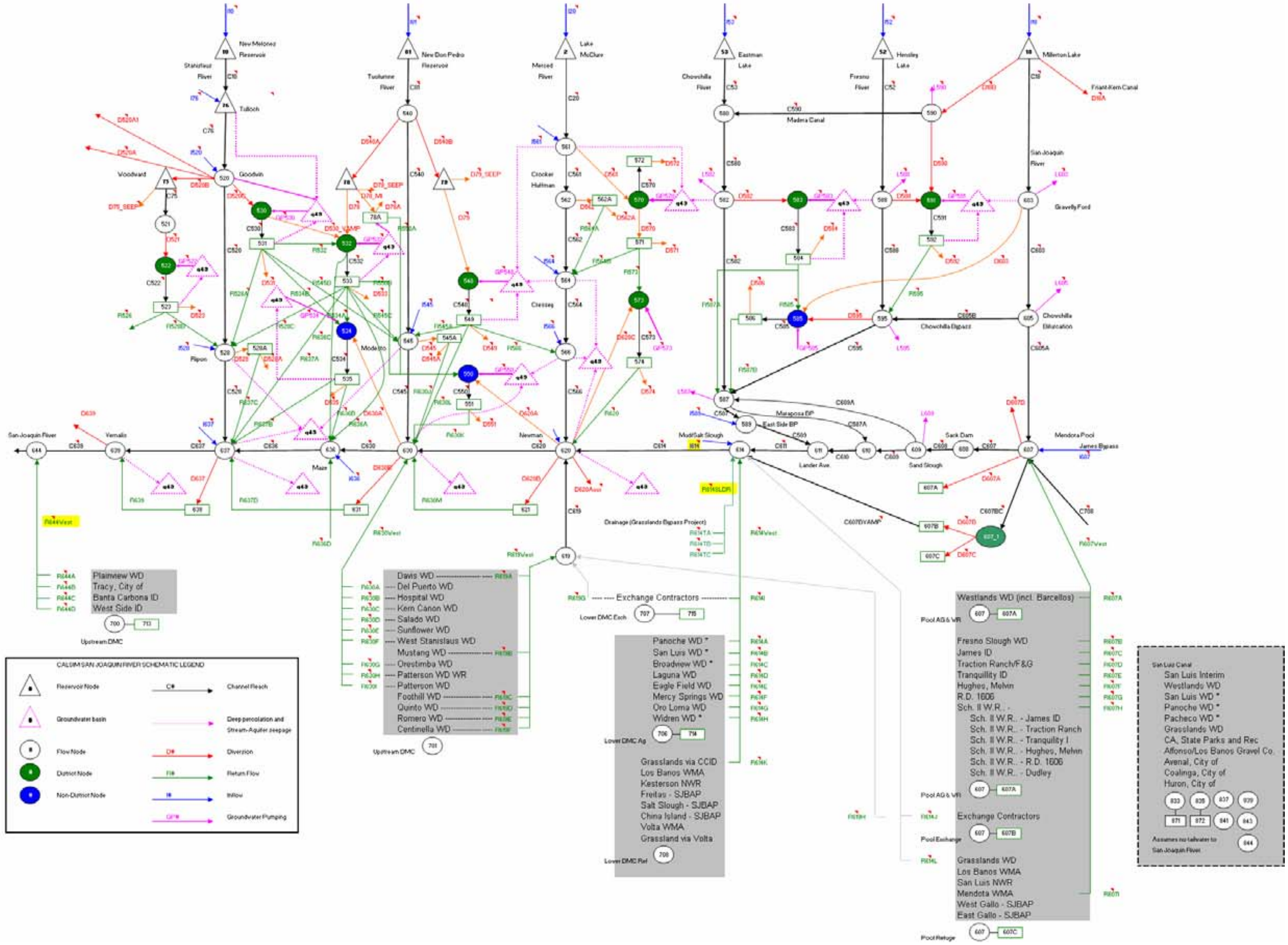


Figure 8 - Flow Schematic for Affected Area

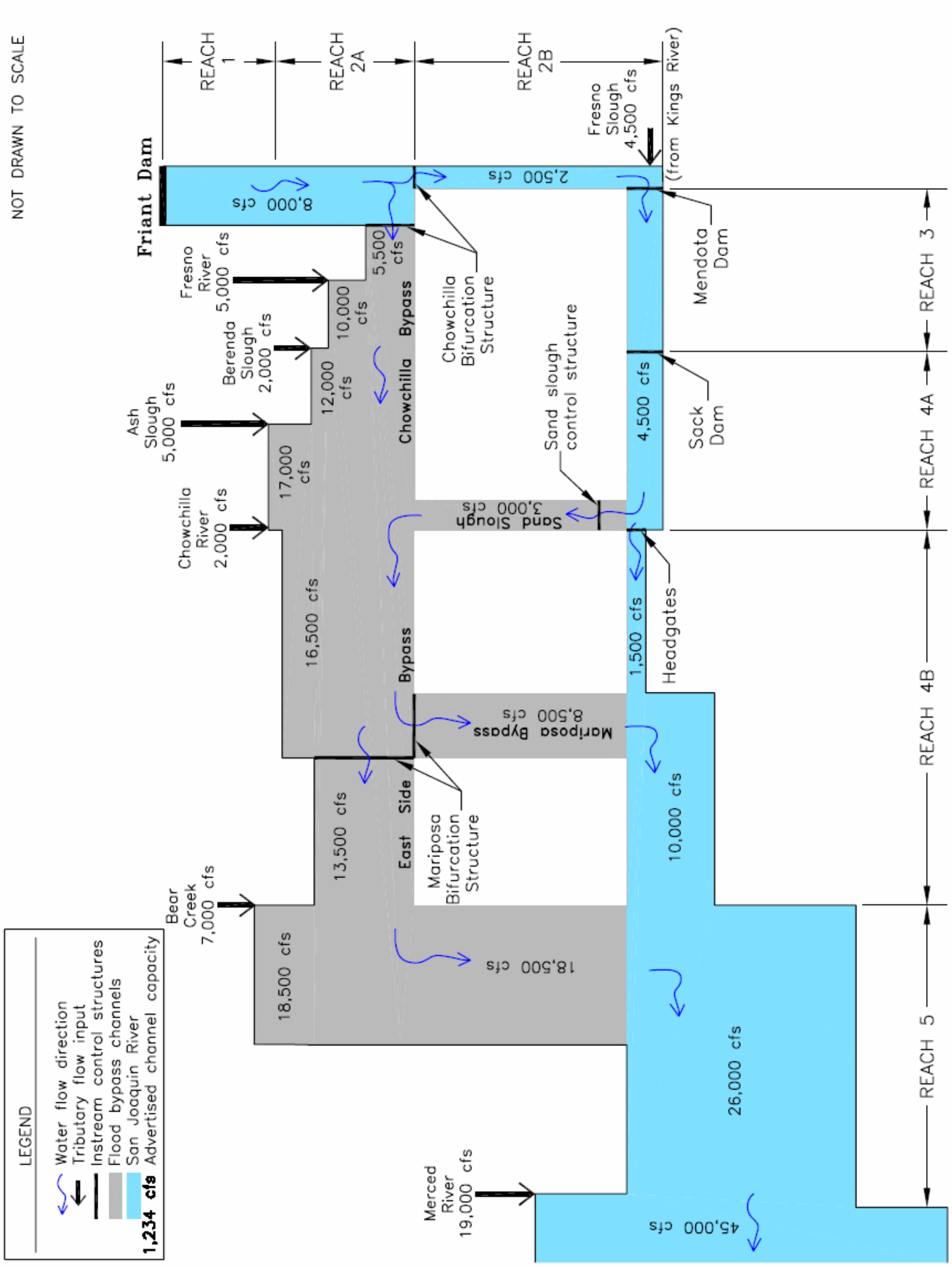


Figure 2-44. Schematic map of structures, flood routing, and reach hydraulic capacity of the San Joaquin River Flood Control Project.

Water Quality Assumption for the San Joaquin River at Lander Avenue (Node 611)

Developed by Dan Steiner, October 2005

Refinements to the CALSIM II depiction of San Joaquin River hydrology upstream of the Merced River confluence have resulted in a revised definition of flows reaching Node 611 (geographically representing the San Joaquin River at Lander Avenue). Prior to these refinements, flow at Node 611 (C611) was a combination of modified accretions (representing ungauged flow, groundwater interaction and gauging errors, relocated from Newman) and flow reaching Node 611 from the Eastside Bypass and the San Joaquin River flow below Node 607 (Mendota Pool and Sack Dam). This prior representation was the result of the original CALSIM II development process, and was modified by the Brekke water quality calibration effort. The quality of water assigned to flow leaving Node 611 was defined by a simple regression equation that resulted in noticeable flows being "better" in quality and minor flows being "worse" in quality. The "load closure parameter" that was applied upstream of Newman generally rectified the errors that existed in the simple regression and other quality assumptions for the other flow components upstream of Newman.

The routing and disposition of flow upstream of Node 611 has been refined to better describe the physical processes that occur in this region. The overarching "accretion" term that was developed for unexplained flow upstream of Newman (previously incorporated into the model at Node 611) has been replaced by the explicit modeling of stream flows from reservoirs (Millerton, Hidden and Buchanan) coupled with explicit seepage in downstream reaches, and an explicit rainfall runoff component for the region. This rainfall runoff component represents runoff that occurs below the region's major reservoirs and from the numerous rainfed streams such as the Merced Streams Group. Review of the results from this effort in comparison to reported flows has illustrated that the prior accretion approach was problematic due to insufficient data.

Subsequent to the refinements, modeled flow at Node 611 represents reservoir releases (reduced for seepage and diversions), Fresno Slough inflow (reduced for diversions and seepage) and rainfall runoff of the region. The water quality assigned to Fresno Slough inflow, flow past Gravelly Ford (San Joaquin River) and the Eastside streams (Fresno River and Chowchilla River, and their tributaries, and the other rainfed streams) is assumed to be 100 µS/cm EC. Flow at Node 611 may have a quality slightly degraded from 100 µS/cm EC if Fresno Slough or San Joaquin River water flowing past Mendota Pool and Sack Dam mixes with water from the Delta Mendota Canal.

By the definition of the hydrology upstream of Node 611, Test Case simulation results (Table 1) show that substantial flow at Node 611 coincides with flood releases from Fresno Slough, Millerton Lake, Fresno and Chowchilla rivers, and rainfall runoff. The nature of this flow is rainfall or snowmelt and thus given a nominal value of 100 µS/cm EC. This value is assumed to representative of all tributary runoff. This value may be modified in the future as additional tributary-specific recorded data is acquired. For instance, recorded data from Gravelly Ford for 2005 indicated that EC at the site varied above and below the assumed value.

Figure 1 illustrates the recorded EC at Lander Avenue during 2005 as a function of flow. Generally, the EC at Lander Avenue can be as low as 100 µS/cm for flows that are greater than 1,000 cfs. For flow less than 1,000 cfs there is a large range for the resultant EC. This circumstance is likely explained by the occurrence of other "base" flows that occur above Lander Avenue, which are not explained by the stream runoff and not explicitly modeled at this time. These flows might include surface return flows from irrigation and refuge operations, and subsurface accretion flow to the stream. These other components of flow would have an associated EC greater than that assumed for the stream runoff component, and when incorporated would increase the blended quality occurring at Node 611, most notably during lower flow conditions. The effort of additionally disaggregating flows upstream of Node 611 would require the spatial refinement of irrigation and refuge operations upstream and downstream of Node 611 and additional analysis of the groundwater interaction upstream of Node 611. For the current level of CALSIM II development, it will be recognized that the simple assignment of the 100 µS/cm EC for flows upstream of

Node 611 will likely lead to an underestimation of load at low flows. This potential underestimation of load will be compensated for through the load closure term that is applied upstream of Newman.

As additional information concerning the historical flow and EC relationship of the San Joaquin River at Lander Avenue Figure 2 through Figure 6 illustrate reported data for calendar years 2001 through 2005.

Table 1

C611 - San Joaquin River Flow past "Lander Avenue" (cfs)

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	0	17	457	374	2416	1233	1739	661	168	65	16	0
1923	16	342	933	912	493	309	958	439	235	98	16	17
1924	16	31	49	49	87	146	134	49	3	0	0	0
1925	0	50	49	49	720	309	555	309	185	16	0	0
1926	16	17	49	49	306	163	672	195	50	0	0	0
1927	0	303	211	163	1726	557	756	309	185	49	16	0
1928	41	411	163	249	369	639	487	163	50	0	0	0
1929	0	34	49	49	126	179	185	179	84	16	0	0
1930	0	1	0	130	198	309	134	98	50	0	0	0
1931	0	17	16	49	54	33	34	33	17	0	0	0
1932	0	0	781	553	2349	440	403	390	235	65	0	0
1933	0	3	33	130	144	260	235	195	168	16	0	0
1934	0	3	49	81	234	146	101	33	17	0	0	0
1935	0	50	98	732	468	731	1455	569	319	81	16	0
1936	16	34	33	179	5852	696	1189	439	235	49	16	0
1937	24	96	98	891	5710	2623	3194	2631	303	81	16	17
1938	39	249	1290	1428	9717	11422	7013	8745	5580	228	65	34
1939	135	329	98	114	270	374	370	179	67	16	0	17
1940	49	37	33	1270	1574	997	622	374	134	33	0	0
1941	16	44	652	731	5745	1976	1455	1447	1665	146	49	34
1942	73	238	890	1625	983	732	682	472	269	114	16	0
1943	16	333	119	3058	833	4624	1194	342	134	33	16	0
1944	16	214	33	81	417	553	269	228	118	16	0	0
1945	0	168	98	98	4037	1581	605	309	202	49	0	0
1946	16	112	367	180	148	362	403	244	101	16	0	0
1947	16	153	232	106	202	163	140	81	34	0	0	0
1948	0	17	16	16	35	163	571	228	134	33	0	0
1949	0	3	16	33	108	488	185	211	101	16	0	0
1950	0	17	16	163	468	146	254	163	67	16	0	0
1951	0	871	4719	2216	556	427	252	211	67	16	0	0
1952	0	34	407	2236	647	4429	2503	4763	3616	114	16	17
1953	178	239	211	534	162	179	202	179	134	33	0	0
1954	0	17	33	114	234	407	303	211	84	16	0	0
1955	0	17	65	195	126	146	168	244	84	16	0	0
1956	0	17	5666	6677	2574	977	380	459	134	33	0	0
1957	16	167	33	49	144	244	168	293	118	16	0	0
1958	8	17	65	146	718	3552	4859	2610	1451	98	33	17
1959	16	181	33	81	378	163	118	81	17	0	0	0
1960	0	20	16	49	278	163	168	130	34	0	0	0
1961	0	34	49	49	72	81	67	49	17	0	0	0
1962	0	0	33	49	2402	747	269	179	134	33	0	0
1963	16	20	16	260	826	362	941	455	185	65	16	0
1964	24	259	81	114	104	146	185	146	67	16	0	0
1965	8	118	829	2217	409	325	1059	293	168	49	16	17
1966	16	462	401	370	309	199	168	130	34	16	0	0
1967	0	34	762	463	453	1404	6224	4546	3090	1401	33	17
1968	16	144	65	81	191	179	137	98	34	0	0	0
1969	2	34	179	6570	13685	10061	9145	9494	9056	331	33	17
1970	99	267	98	2315	414	867	218	163	101	16	0	0
1971	0	50	293	260	166	195	168	179	118	16	0	0
1972	0	34	130	81	156	114	118	81	34	0	0	0
1973	0	34	65	358	1926	1433	608	356	118	16	0	0
1974	24	146	214	1366	310	1014	975	304	101	16	0	0
1975	6	148	65	98	927	960	739	423	202	49	0	0
1976	22	182	49	33	104	130	84	49	17	16	0	0
1977	0	17	16	33	18	16	17	16	17	0	0	0
1978	0	0	146	1171	4419	5941	8834	6090	1050	65	16	17
1979	0	210	49	584	1194	1474	528	260	101	33	0	0
1980	16	34	49	3824	6819	6043	2014	1053	151	49	0	0
1981	0	202	49	179	144	276	185	65	17	16	0	0
1982	24	67	114	1078	2700	3128	8856	4895	1341	81	33	34
1983	80	2967	8231	10177	15064	15856	10742	10809	9822	4433	49	34
1984	494	3437	6114	4131	506	368	218	98	50	16	16	0
1985	16	84	81	86	220	293	202	65	34	0	0	0
1986	16	50	114	130	8090	9018	4303	3212	1509	16	0	0
1987	16	223	33	49	144	211	67	33	34	16	0	0
1988	4	17	33	81	52	81	101	33	17	0	0	0
1989	0	0	33	33	72	228	84	33	17	0	0	0
1990	0	17	16	49	54	81	50	33	17	16	0	0
1991	0	1	0	16	18	683	185	81	50	16	16	0
1992	4	1	16	33	452	195	118	33	0	33	0	0
1993	0	0	65	2056	1207	983	644	273	1144	83	33	0
1994	33	223	49	33	126	65	84	114	34	0	16	0
1995	0	17	33	1492	2291	6023	5261	6747	768	3666	16	34
1996	207	193	81	282	1820	1843	529	815	84	65	33	17
1997	8	776	5768	21358	5939	503	286	136	34	16	0	0
1998	16	110	65	1113	7296	3244	6442	6996	6424	3804	16	34
1999	71	299	106	254	599	260	403	179	84	16	16	34
2000	33	17	16	244	2459	1155	372	195	67	0	16	17
2001	33	17	33	98	234	409	239	98	17	16	16	0
2002	0	17	211	244	144	244	101	81	17	16	16	0
2003	0	50	179	130	108	146	202	211	67	49	16	0

Figure 1

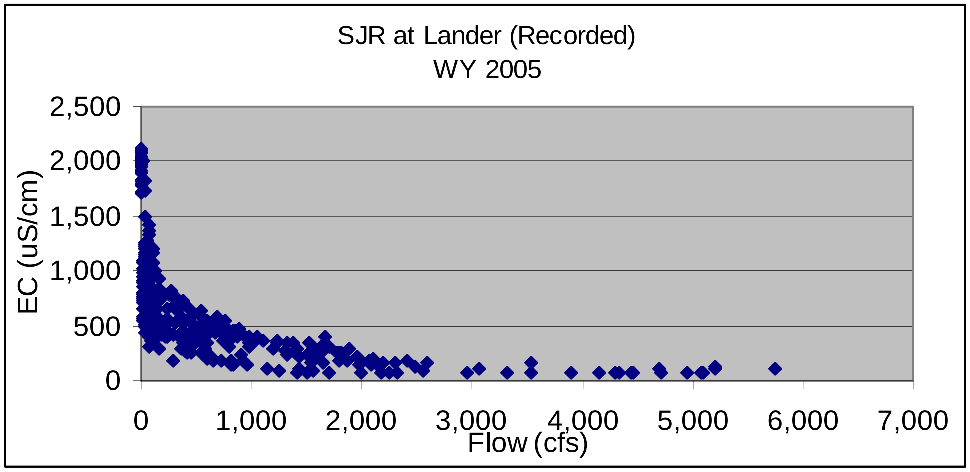


Figure 2

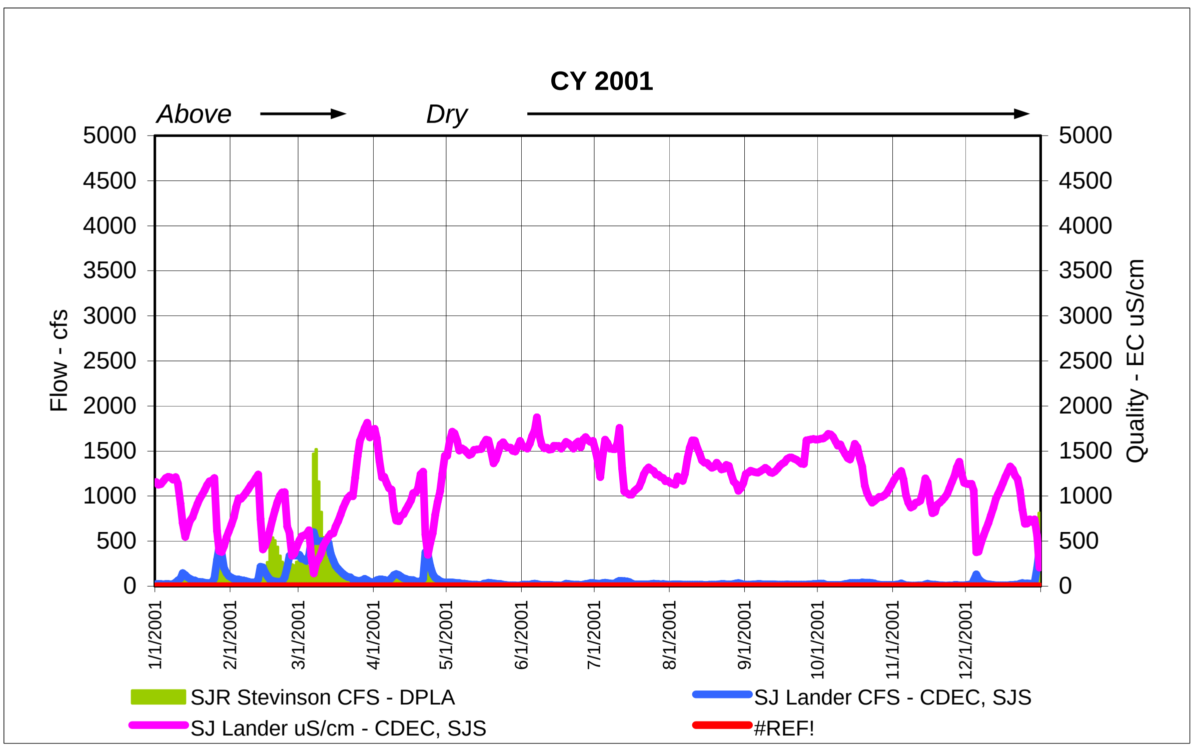


Figure 3

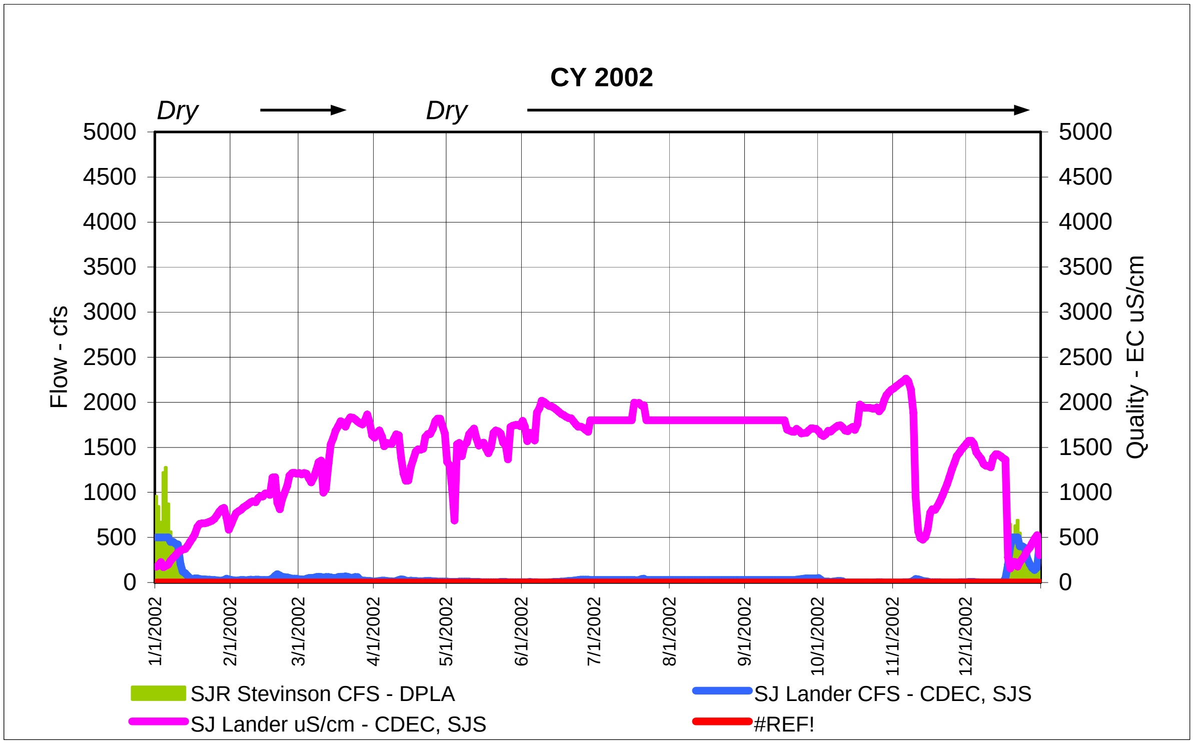


Figure 4

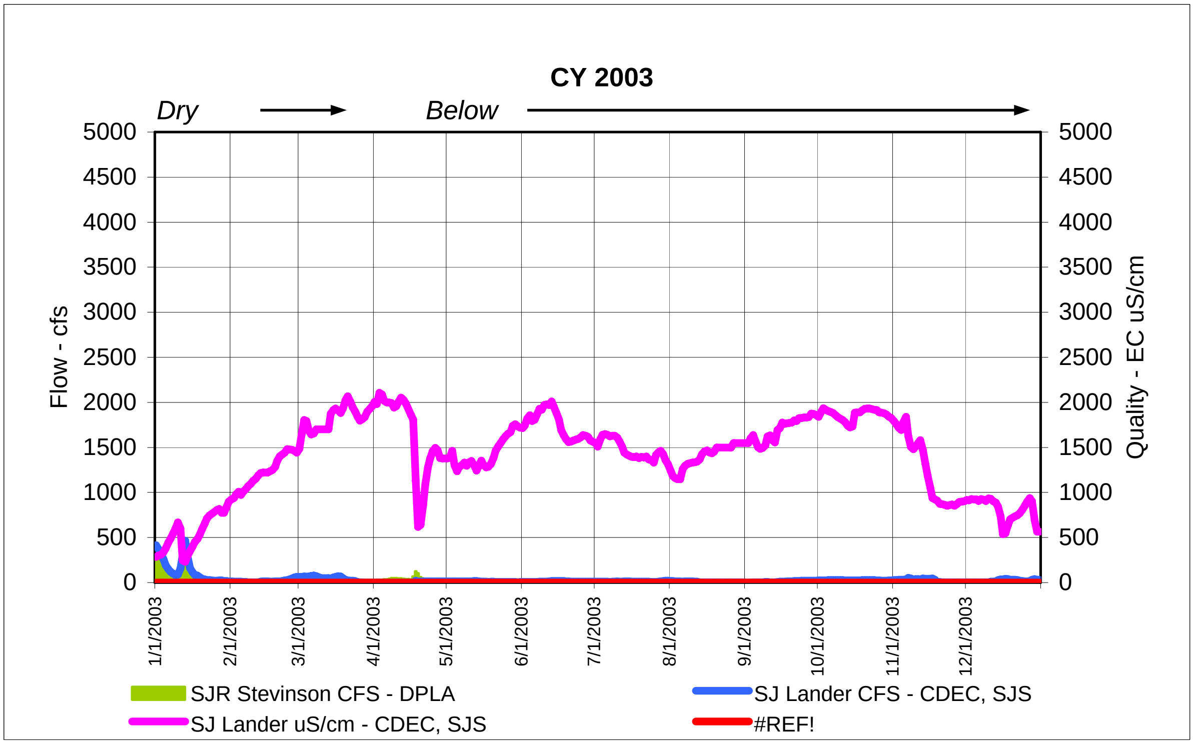


Figure 5

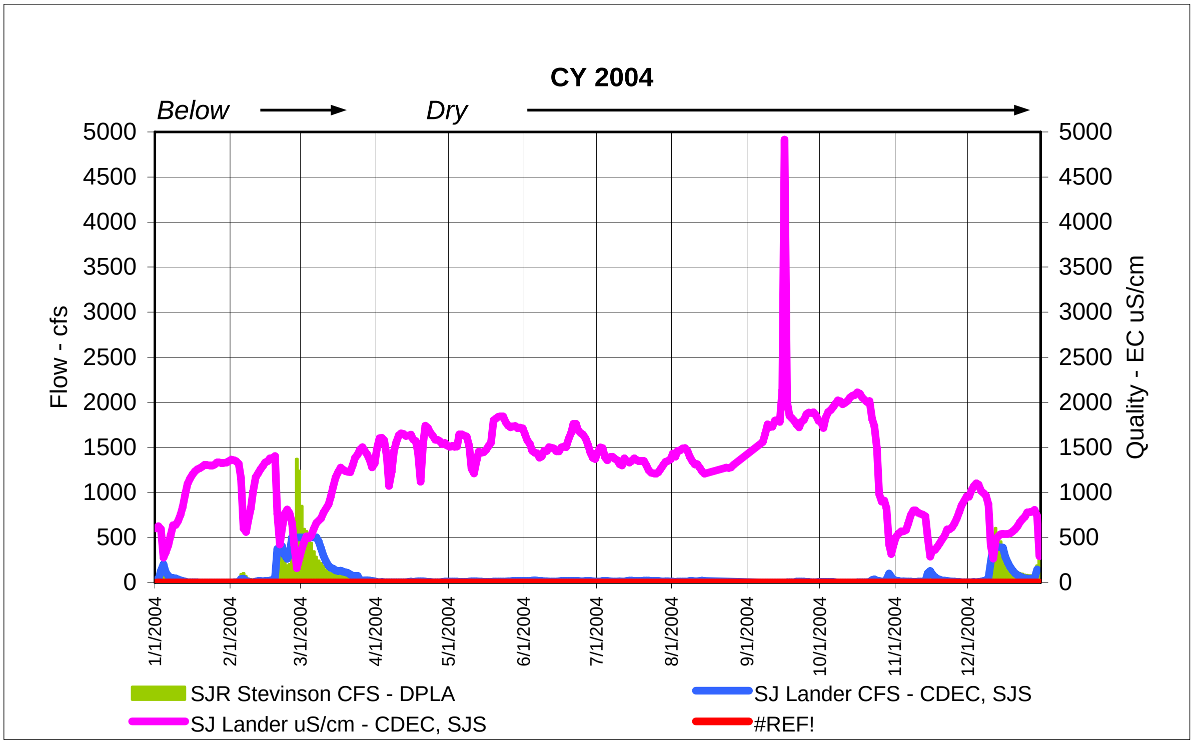
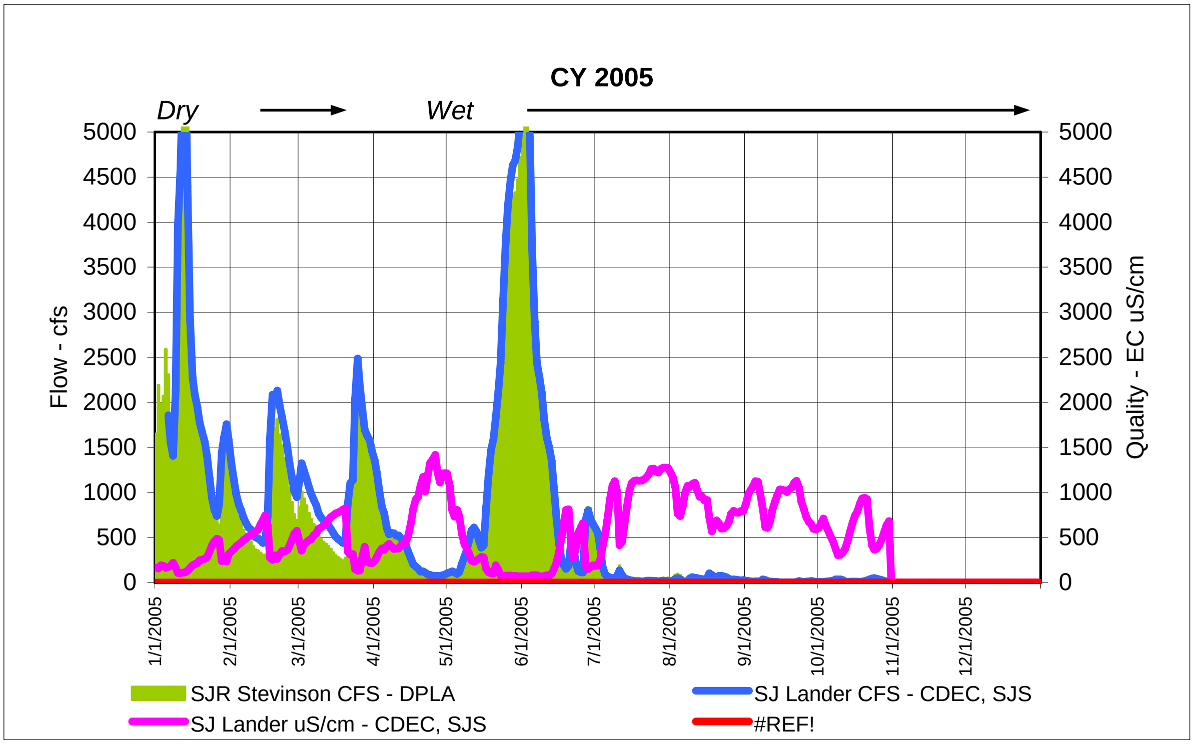


Figure 6



SAN JOAQUIN HYDROLOGY EXTENSION

Development of a CALSIM data set and simulation for the San Joaquin River Basin that simulates water year 1922 through 2003 has been completed. Prior to this effort a data set had been prepared that allowed CALSIM to simulate San Joaquin River Basin operations through 1998. This memorandum describes the hydrology extension from 1999 through 2003 and the CALSIM simulation.

Extension of Model Inputs

The extension of CALSIM input data through water year 2003 included the extension of the following reservoir inflows, stream accretions, minimum instream flows, irrigation diversion requirements, water quality parameters, and miscellaneous data.

<u>Monthly reservoir inflows for Millerton Lake, Hensley Lake, Eastman Lake, Lake McClure, Don Pedro Reservoir, New Melones Reservoir, and New Hogan Reservoirs.</u> Monthly inflows to Hensley Lake, Eastman Lake, Lake McClure, New Melones Reservoir, and New Hogan Reservoirs were extended using recorded or computed historical flows. Millerton Lake inflow was extended using the USAN model, which was also extended to simulate operations upstream of Millerton Lake through water year 2003. A revised simulated inflow to New Don Pedro Reservoir was provided by the City of San Francisco for the 1922 through 2002 period that represents current planning results. The inflow to New Don Pedro Reservoir for 2003 was extended using computed historical flows.

<u>Several CALSIM parameters were extended for 1999 through 2003 using the same methodology used for developing data for the 1922 through 1998 period. That methodology is described in the current documentation titled "CALSIM II San Joaquin River Model (DRAFT)", USBR, December 2004 (CALSIM SJR_DRAFT_Version2_051805.doc).</u>

- <u>Stream accretions and depletions.</u>
- <u>Minimum instream flow requirements.</u>
- <u>Irrigation diversion requirements.</u> The DWR CU model was extended, modified, and rerun for each San Joaquin Basin demand areas for the current LOD.

<u>Water quality input parameters</u> were extended using the same methodology as is used for the 1922 through 1998 period. This methodology is described in the documentation titled "San Joaquin River Water Quality Module Version 1.00 for CALSIM II", USBR, December 16, 2004 (Report_WQModuleVer1.00_Draft_121604_BodyText.doc). The water quality closure term for above Newman and Maze to Newman was extended using the same methodology as is used for the 1922 through 1998 period, which requires running CALSIM iteratively.

<u>Flood control limits, reservoir levels, and San Joaquin River year types</u> were extended using acquired information, repetition of constant values or computation of allowable values.

Parameters describing Merced ID demands and return flows were revised based on recent data provided by Merced ID. Revised parameters are located in both WRESL code and lookup tables and revise operations for the entire simulation period.

Evaporation data were extended with “dummy” data by repeating existing data. DWR is extending reservoir evaporation data for all reservoirs in the system.

Development of CALSIM Simulation
The common assumption version of CALSIM was modified and used for this work effort. The conveyance step of the model was modified to simulate the San Joaquin River Basin as a stand alone model. Interaction of the San Joaquin River with the DMC and Delta were extended through time-series input in this version of CALSIM.

Since the Mokelumne River system is simulated in CALSIM with the San Joaquin River system and the extension of the Mokelumne system hydrology was not part of this work effort, the Mokelumne system data were extended beyond 1994 with “dummy” data in order to produce the CALSIM simulation.

Three lookup tables were extended:
1. X2days.table (extended with dummy data)
2. wytypes.table (extended with dummy data)
3. wytypessjr.table

Validation
Inspection of the output demonstrates that the simulation is reasonable and compares to recent history fairly well. Plots comparing simulation results to historical operations are included in the attached *output.xls* spreadsheet.

Further refinements in progress
There are additional refinements to the simulation that are currently under development. These refinements include additional disaggregation of the hydrology upstream of the Merced River confluence, with a redefinition of associated water quality. At the time of that additional effort, further modifications to the San Joaquin River Basin simulation will occur. Also, a simulation depicting the 2030 level of development for the San Joaquin River Basin is expected to be completed shortly.

Attachments and Associated Files

<<CALSIM_code.zip>>
    Contains the CALSIM WRESL code, input, and output
<<SAN JOAQUIN HYDROLOGY EXTENSION.doc>>
    Documentation of extension
<<Spreadsheets.zip>>
    Contains all input
<<Output.zip>>
    Contains output and validation plots